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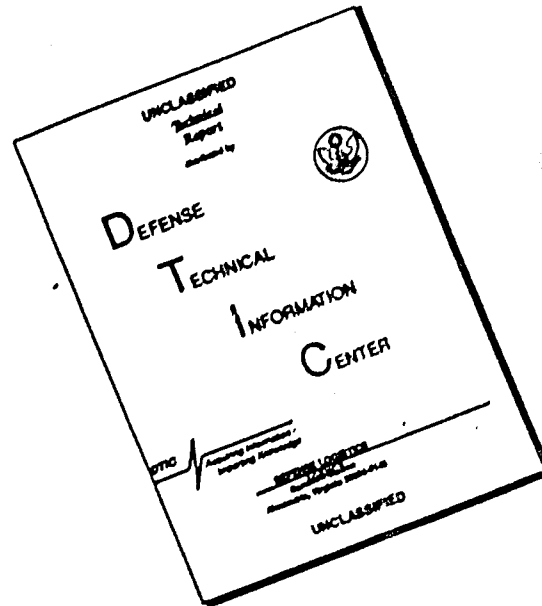


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WORK OF THE NIKOLA TESLA ELECTRO-TECHNICAL INSTITUTE  
IN BELGRADE IN 1961  
by B. Mitrakovic, et al  
- Yugoslavia -

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WORK OF THE NIKOLA TESLA ELECTRO-TECHNICAL INSTITUTE  
IN BELGRADE IN 1961

- Yugoslavia -

[Following is the translation of an article by B. Mitrovic, S. Despotovic, V. Knezevic and D. Skemdzic, employees of the Nikola Tesla Institute, in the Croatian-language publication Casopis za elektroprirodu i elektroindustriju (Periodical For Electroeconomy and Electro-Industry), No 5, May 1962, Belgrade, pages 277-234.]

In agreement with the concepts of the organization of scientific and research work in the People's Republic of Serbia, the work of the former Nikola Tesla Institute has been reorganized. A brief review of the past organization of the Institute, its relationship to the organizers of the Institute, as well as a review of the work of the Institute in 1961 are given in this article. Toward the end of the article, a brief review of the more important work accomplished at the Institute during 1961 has also been given.

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The Organization and the Responsibilities  
of the Institute

The Electro-Technical Institute Nikola Tesla in Belgrade began work on 1 July 1961, inheriting the old Institute for Survey of Electrical Phenomena Nikola Tesla, according to the Regulation No 148, issued 25 March 1961 and published in the Official Gazette of the People's Republic of Serbia. In agreement with the concepts of the organization of scientific-research in the People's Republic of Serbia (by reorganizing the old institutes or building new ones), the official organizers of the Nikola Tesla Electro-Technical Institute are: The Federal Executive Board of the People's Republic of Serbia; The School of Electrical Engineering in Belgrade; Belgrade's Elektrosrbija Enterprise; and the Mosa Pijade Cable Factory in Svetozarevo. The organizers are

represented by two members in the Institute's Council, and the employees elect four members.

The Nikola Tesla Electro-Technical Institute is registered as a scientific institution which operates financially on the principles set for economic enterprises.

In agreement with the needs of our electro-economy and electro-industry, and in agreement with the organizers of the Institute, the organizational chart of the old Institute has been changed. By doing this, particular attention has been given to the basic responsibilities of the Institute.

Figure 1 represents the organizational chart of the Nikola Tesla Electro-Technical Institute. [All charts, illustrations, etc. are appended at end of text.]

Basic responsibilities of the Institute are: the application of scientific methods in studying, researching, and solving of all problems in the field of electro-economy and electro-industry; the finding of forms and possibilities for the application in the practice of all scientific achievements; the organization of various forms of scientific work and highest education; and to help in organizing and performing teaching activities during post graduate studies at the School of Electrical Engineering.

In the field of electro-economy, particular attention is given to the: studies of high voltage network systems; forms of such systems; analysis of electric power systems; problems of distribution of power in the system; problems of short circuits and stability; studies and analysis related to the problem of transferring electric power on long distances; problems related to the electrification of agriculture etc.

In the field of electric power the following is being studied: the theoretical and practical questions which influence modern industrial production; the basic problems upon which the institution of new industries are based; the joint work with the industry for possible improvements; the research and scientific approaches and principles; the existing production of new electro-technical products; the introduction of new electro-technical materials in our industry, etc.

The scientific and research work performed by the Institute in the past can be classified into several categories. First, there are long range (4-5 years) projects. These projects represent the studies of interest to our society. Second, medium range (2-3 years) projects; these projects are mostly related to the problems of interest to our economic enterprises. Last, the short range projects; these projects have been worked out by the three electro-industrial departments. Here are included: the design of various apparatus and equipment used by economic enterprises in controlling and improving production, and which are not produced in series either abroad or in our country. A special class of work represent daily

investigations of the economy, as well as the performance of studies of various proto-types or elements of a product during its production, and for the purpose of achieving better quality.

The percentage participation of users interested in the services offered through the research-scientific work of the Institute is as follows:

1. Economic and industrial enterprises	38%
2. Federal Fund for Scientific Work	21%
3. The Union of Yugoslav Electro-Economy (ZJE)	14%
4. Republic Fund for Scientific Work of the People's Republic of Serbia	10%
5. Other	7%
6. The Union of Electro-Economic Enterprises of the People's Republic of Serbia	10%
7. Secretariat for Industry of the People's Republic of Serbia	4%

All scientific research work, as well as any other work is done by the Institute's permanent and associate staff. The associate staff constitutes almost all the professors of the Power Department of the School of Engineering in Belgrade, as well as a certain number of engineers from the research and development laboratories of economic enterprises.

The classification of the personnel according to the qualifications, is given in the following table:

	<u>Permanent</u>	<u>Associate</u>
Engineers and university graduates and other personnel	34%	100%
Technicians and other personnel with high school qualifications	32%	
Qualified and highly qualified workers	18%	
Office personnel with eighth grade education	16%	

Because the Institute started with its work on 1 July 1961, no indicators can be given which would show the progress of the Institute in this short period of time. But, it will be useful to note that in the period between 1 July 1961 and 31 December 1961, the Institute had 2.5 greater income than in another period of the same length, i.e., in the period between 1 January 1961 and 30 June 1961.

Increased income of the Institute had its effect on the profit, which made it possible for the Institute to secure new equipment for the laboratories, and to provide some funds for financing the research-scientific work at the Institute.



## Review of Work by Departments

### I. Department of Electro-Economy

#### 1. Study of electric power systems, 110 and 220 kV in the People's Republic of Croatia, for 1962

This study represents the first work done in our country dealing with the analysis and study of static and dynamic stability of electric power systems. The new 220 kV power line Mraclin-Split, 356 km long, which is supposed to transfer large amounts of power from the Dalmatian power plants to the north-western part of the system, required a solution of the static and dynamic stability of the system. The study, taking into account the most representative plants, determines the conditions under which the system will be stable.

The study treats in detail the following questions: the configuration of the central and western section of the Yugoslav 110 and 220 kV network, the plan of work of plants and consumers, the choice of characteristic conditions and kinds of disturbances for which the system should be examined, the variation curve at the source as the criteria for dynamic stability, the limits of static stability, etc.

#### 2. The examination of the 110 and 220 kV system in Slavonia for the 1962-1970 period.

The basic goal of the study is to develop in Slavonia such a configuration of the network which would secure a reliable functioning of the system. After examining several alternate combinations, the configuration of the network for the 1962-1970 period has been determined. Particular attention has been given to the problems of compensation and selection of satisfactory voltage conditions, because Slavonia is known as the region without sources for electric power.

Finally, the study solves the problem of providing Slavonia with electric power.

#### 3. Study of the stability of the 110 and 220 kV electric power system in Yugoslavia for 1962 and 1963.

The development of the 220 kV network in Yugoslavia, which will incorporate almost all Yugoslav territory by the end of 1962 and during 1963 and the new, powerful sources of electric energy, located far away from the consumers require a transfer of large quantities of electric power over long distances. Such working conditions create the problems of static and dynamic stabilities. The basic goal of the study was to determine the characteristics of the switch as a means which would secure a normal and stable work of the system in the cases of large defects. The dynamic stability of the system has been investigated by applying the step-by-step method, while using the network analyzer. Static stability has been

checked by using three methods: the method of synchronizing power coefficients, the method of the first derivation of reactive power by voltage.

The configuration of the 110 and 220 kV networks in Yugoslavia the plan of work for electric power plants and consumers, the voltage conditions, the oscillating curves of the source, and the criteria of static stability have been worked out in detail.

The study will provide a basis for the correct selection of protective systems, as well as the methodology for investigation of systems on static and dynamic stabilities because in the rapid development of our network high-power voltage the problems of stability are of primary importance.

4. The investigation of the 110 and 220 kV network in the People's Republic of Serbia in 1961.

The regular work of the system greatly depends upon the willingness of the dispatcher's service to control the system. An excellent tool in achieving the only correct, sure and economical work of the system is the analysis of such working conditions which are expected in the work of the system. The analysis of such working conditions, already done in one of the previous studies, offers the optimal solutions to the problems which are usually met in the every day's practice and in actual situations developed in the service of dispatching. The study elaborates about thirty situations which could have all been expected in 1961, and offers the dispatcher's service as the most suitable solution for controlling the system.

The study elaborates in detail the configurations of the system which are expected in 1961, the plan of work for sources of energy and consumers, the solutions to about thirty different situations which have been expected in the actual work of the system, the voltage conditions and the load of the lines, the compensation and volume of inter-connecting transformers, etc.

This study, with its clearly defined goal greatly helped our dispatcher service by offering help for a correct exploitation of electric-power systems.

5. Short circuits in the 110 and 220 kV electric-power systems in the People's Republic of Serbia for 1961.

A regular functioning of the protective service of electric systems requires a knowledge of all kinds of short circuits which can occur in the system. In this respect many detailed measurements have been made, and the currents in short circuits have been calculated. The network of direct, inverse and zero line have been examined. In this way all necessary data required for the determination of all current intensities at which short circuits occurred.

Beside other material, the study elaborates the configuration of the 110 and 220 kV network in the People's Republic

of Serbia, the influences of the systems in other People's Republics, the transition and permanent currents in the short circuits the transition and permanent reactance of the system, the disconnecting power, and the zero component of the transition and permanent currents in the short circuits. All of these results have been presented in a form convenient to use in practice.

6. The prospects of the consumption of electric power in agriculture in the territory of the Autonomous Region of Vojvodina and the northern region of smaller Serbia, for the period between 1961 and 1965.

By the methodology used, and by the way in which the problem has been treated, this study is the first of its kind in our country, and will no doubt be of great use to the electro-economy and agriculture.

The study treats the problems of: modern industrial agriculture (large farms of the socialist type, factories for cattle food, boilers and drying plants for grain and herbs, etc.); irrigation and flood control of large farms of the socialist type; the power needs of agriculture; the possibility of providing electric energy; tariff and economic problems; and prospective needs for electric power in agriculture.

7. The methodology in investigating and analyzing the working conditions of network analyzers.

The study elaborates the methodology of planning examining and analyzing of future development of the systems. The needs for such methodology was noticed a long time ago because various segments of the electric power system in Yugoslavia were studied and planned by different authorities. This study, as well as the methodology presented, will no doubt contribute toward a uniform and faster planning of development of electric power systems, the consequence of which can be large savings in investments for future electric power objects.

Beside a series of questions, this study treats in detail the preparation of basic power data for studying the electrical networks, the incorporation of the power plants into the system, the study of the system, basic studies of the system's components (the distribution of power, voltage conditions, short circuits, stability), the application of network analyzers, etc. The application of the methodology has been shown in several examples.

8. The methodology of planning of reactive powers:

The study developed a system which by using the future needs in reactive power, the sources of reactive power, the economy of the location of the source of reactive power, and the balance of reactive power can be determined.

This study gives a basis for a uniform way of planning reactive power and allows the achievements of optimum technical-economic solutions.

9. Study of the regulation of frequencies and power exchange in the electric power system in Yugoslavia:

The problem of regulation of frequencies and power exchange has been evaluated in this study for the first time in our country in such a documented manner. After the advantages of the automatic regulation of frequencies and power exchange have been described, a series of methods applies abroad and related to the method of regulation have been also given in this study. The description has been given for the:

- 1) Procedure in regulation without integration of the regulated value, and thus:
  - a) direct regulation without the network regulator,
  - b) indirect regulation with the network regulator-integrator.

The characteristics of the most frequently applied regulators and installations for automatic regulation of frequency and power exchange have been given. Having in mind the present stage and the prospective development of Yugoslav electric power system and because the power plants regulators have been chosen, a new system of regulating the frequencies and power exchange as well as the organization of dispatcher service in Yugoslavia have been proposed.

## II Department of Survey and Regulations

1. The manufacturing of electromechanical equipment for transformation and regulation of frequencies and voltage for feeding the IBM 705 calculating machine.

This problem has also been studied some time ago with the help of the Energoprojekt enterprise. During this year, the third transforming group has been completed and started to work in the Electronic Center of the Federal Authority for Statistics. All three groups serve for feeding the IBM-705 calculating machines. The groups consist from electromechanical transformers of frequencies and regulators of frequency 60 Hz, as required by the IBM propositions. The power of each transformer group is 100 kVA. In the construction of transformer groups and regulators with magnetic amplifiers and gas pipes (tiratrones?), many new and successful solutions have been applied. An installation has been made to perform a full automatic job.

Beside the construction, the Institute controls and maintains the transformer groups which are working in the Electronic center continuously during three shifts.

2. Manufacturing of stabilizers of voltage and frequency.

The projected and constructed regulators are of the

electro-mechanical type with rotating transformers by means of which the correction of frequencies and voltage in the network are made. The performances of these regulators are 380/220 V and 50 Hz with the regulation of frequencies of  $\pm 0.2\%$ . According to the request by the Radio-Television Belgrade, the regulators have a power of 40 kVA and serve to feed one section of the building with a constant voltage. The frequency regulation in the studio of a radio station is necessary because of the need for a permanent and constant speed of rotation of tape recorders and record players, both during the filming and reproduction of the program. In this manner the time required for the program can always be calculated in advance.

3. The manufacture of equipment for analysis of micromotors.

This equipment has been built according to the ideas submitted by Dr. Ing. Ilija Obradovic and Dr. Ing. Petar Miljanic. The equipment was intended for serial analysis of certain types of mecor-motors, especially for the separate analysis of stators, rotors, and complete motors. By the help of such equipment, all errors in the windings of the motor can be detected. The errors are registered by light signals, so that this kind of equipment can be used also by operators with but a little training. The equipment contains relays which react to the light signals indicating errors, and which are combined with electronic amplifiers.

4. The manufacturing of equipment for the investigations of magnetic metal materials.

This equipment is in fact a small Epstein apparatus, built according to the contemporary concepts in analyzing the magnetic metal materials when samples heavier than 2.5 kg are used. According to the classic Epstein's method, which required samples of 10 kg., the greatest advantage of such modern apparatus is in the smaller quantity of required metal materials which, in the serial analysis represents a significant saving, as well as the saving in time. The investigations which have already been made abroad indicate that the use of smaller amounts of samples does not influence the correctness of the measurements. The equipment built contains a system for compensation of losses in the windings, as well as the instruments which allow direct reading of the field intensity (in A/m) inductivity (in T) and losses (in W/kg). The application of the above described instruments allows direct readings and avoids calculations after the measurements have been made.

With the apparatus of Epstein, the transformer of frequencies with an asynchron motor containing the wound rotor which allow us to obtain fixed frequencies of 30, 40, 50, 60 and 70 Hz has also been delivered. This range of frequencies

has been sufficient for the purpose of separating losses in the analyzed winding. All elements for measurements, impulses to the regulator of frequencies and the adjustment of the wanted field, i.e., inductivity, are located, together with the Epstein apparatus, in a wooden box. The small apparatus is shown in Figure 2.

5. The manufacturing of equipment for measuring of the resistance of transformer windings.

The equipment has been made completely from domestic materials. It consists of elements for adjusting the electric current, for analyzing the winding, and the elements of measuring by using one instrument, by applying the method of measuring the voltage and current. It has only seven ranges, with the lowest one of 1 mΩ, and the highest of 450 Ω, whereby the needs for the present production program of the Dinamo enterprise have been satisfied.

### III Department of Equipment and Materials

1. Measurements of currents of atmospheric discharge of electricity by using magnetic rads.

The study treats in detail the method of measuring the currents of electrical lightening bolts by using magnetic rods, adopted by the Nikola Tesla Electro-Technical Institute. In fact, this is a modified method of one of the organizers of such measurements in the world, this of Swedish professor Norinder.

In the study there have been given: the instructions for measuring the current of electrical lightening and a detailed description of the construction of measuring devices and the equipment used. The instruction for practical measurements on power lines and transformer stations have also been given.

2. Measurements of the pre-voltage of atmospheric and operational origin by using clidonographs [?].

The study first examines various methods used in measuring the pre-voltage which are applied elsewhere in the world. The measurements of pre-voltage of atmospheric and operational character by using clidonographs have been treated separately. This method is already applied abroad. However, here we have the case where the clidonograph has been designed and produced in the Nikola Tesla Electro-Technical Institute. The last section of the study contains detailed instructions for practical measurements of prevoltage on power lines and transformers. These instructions are based on experiences collected during practical and laboratory experiments related to the problem in question.

3. The design of the chart representing wind and atmospheric discharge of electricity on the territory of the People's Republic of Serbia.

The Nikola Tesla Electro-Technical Institute has been dealing with this problem for several years. Beginning in 1960, the Union of Electro-Economic Enterprises of the People's Republic of Serbia also became interested in this problem. In the past year, the first charts representing winds and the atmospheric discharge of electricity have been made.

This work has been continued during this year, and more data from previous years have been accumulated and treated in different ways. The isoceraunic charts have been made. The basis of these charts have been the average number of thunder storms during the year, the period of duration of the phenomena and finally the direction of the phenomena. Related to the wind, charts indicating the directions and maximum and average wind velocities have been made.

4. The measurements of the currents of atmospheric discharge of electricity and the pre-voltage of the atmospheric and production character.

With the constant cooperation with the Elektroistok enterprise in Belgrade, during this year, the measurements of currents of electrical lightening and prevoltage of the atmospheric character on power lines and transformer stations in the People's Republic of Serbia have been made. This year the program is somewhat broader. There exist now about 2,000 measuring places for measuring the currents and about 500 places for measuring the pre-voltage. Although the measurements started in 1960, good results have been achieved.

These results will greatly help in designing and maintaining the power lines. At present, the measurements are being made on power lines and transformers' stations which are most exposed to atmospheric discharge of electricity. Gradually, the measurements will be collected on other power lines and transformer stations. Therefore, we intend to increase the number of measurement stations in 1963 by about 30%. [See figure 3]

Figure 3 shows the installation of the clidonograph on the 110 kV power line under load.

5. The study and the manufacturing of equipment for cutting the striking waves of load and the excitation of striking load generators.

Such installation is necessary during various investigations when striking load generators are used, and when the wave is to be cut after a certain time interval. The same equipment can be used for the exciting of various types of striking generators. The study and the manufacturing of this equipment has been made by using the data from foreign

literature. The installation for cutting striking waves can be adjusted to any striking load generator by using an additional distributor. The installation has been designed so that the dissipations of time required for reaction in the case of several consequent strikes is almost negligible. This equipment for cutting the striking waves are shown in Figures 4 and 5.

6. The study of the method of testing of motor and protective joints based on the principle of "cataract", and the manufacturing of proto-types of two testing panels for investigation of currents, voltage and for other tests in the production.

In this study the construction of joints on the principle of "cataract" has been studied. Their qualities have been analyzed in detail and comparable review of characteristics of the switch with the "cataract" and other switches have also been given. [Figure 5]

On the basis of the study two installations in the form of test desks have been built. The first installation consists of two parts: one section is supposed to register the action of the trigger with the currents up to 2 In, and the second section is supposed to register the action of the trigger with the currents up to 10 In. For measuring the currents two current transformers have been built in. The transformers have four and six volumes, and with the help of the specially designed electronic equipment and a synchronic clock, the time of work between 0.1 - 0.3 sec. can be measured. The view of the whole test desk is shown in Figure 6. The installation for current tests can handle several samples simultaneously. Every break through is signalized and in the case of an irregular sample the equipment disconnects automatically. The view of the desk for testing of voltage is shown in Figure 8. When designing the manufacturing such testing equipment, it is important to achieve that the process of operating this equipment be as simple as possible, and that a large number of samples can be tested in the shortest period of time. In Figure 7 an inside view of the equipment for testing currents of protective switches is given.

7. The design and the manufacturing of two high voltage installations of 0.1 and 3 kV and of 1. to 15 kV for testing voltage of motors in serial production.

The designed and manufactured installation in the form of a testing desk should serve as the place for testing voltage of various machines having a nominal voltage up to 6 kV. The regulation of voltage is continuous, and the readings are made on the side of high voltage. The installation is equipped with all possible protective elements for the purpose of protecting the personnel. The signal lights have been built in and they show that the system is under load,



that the object is being tested, that the break through occurred, etc. Both installations have been equipped with the mobile protective fence with the attention light.

8. The design and the manufacturing of high voltage transformers for currents up to 20 kV.

Because of the frequent need for alternate current of great intensities, the seconder [?] of the projected transformer is built from copper collectors, with the great possibilities of combining, depending on the value of the secondary current needed and the characteristics of the load. The transformer can be very useful in testing the low voltage fuses, thermal stresses of cables, distributors and the triggers of primary relays, some stresses in the case of boundary currents, etc.

#### IV The Department of Machines

This Department was organized in the middle of 1961 and it was not possible to complete any study in this short period of time. The Department is working on several medium range studies, the termination date of which is set for 1962 and 1963.

#### V Other Works

Beside the listed studies and building of various equipment, to which the extensive scientific and research work preceded, the three electro-industrial departments of the Institute have completed a series of various tests in the past year.

The Department of Survey and Regulations tested a large number of measuring, current and voltage transformers, has built several special current transformers, controlled and tested a large number of different measuring instruments, tested the magnetic materials, accumulators, etc.

The Department of Equipment and Materials tested, according to domestic and foreign standards, various high voltage equipment (cables, special cable heads, auto cables, special kinds of isolators, distributors of prevoltage, etc.) as well as the low voltage equipment (the proto-types of various automatic, rod and piston switches, highly effective fuses, relays, bimetal elements, the distributors of ignitions in automobiles, spark plugs, etc.), electro-technical materials (rubber products, products made from bakelit, various oils, etc.), and electrical household appliances (boilers, heaters, thermostats, irons, etc.). [See figure 8]

The Department of machines tested a large number of electrical machines and transformers.

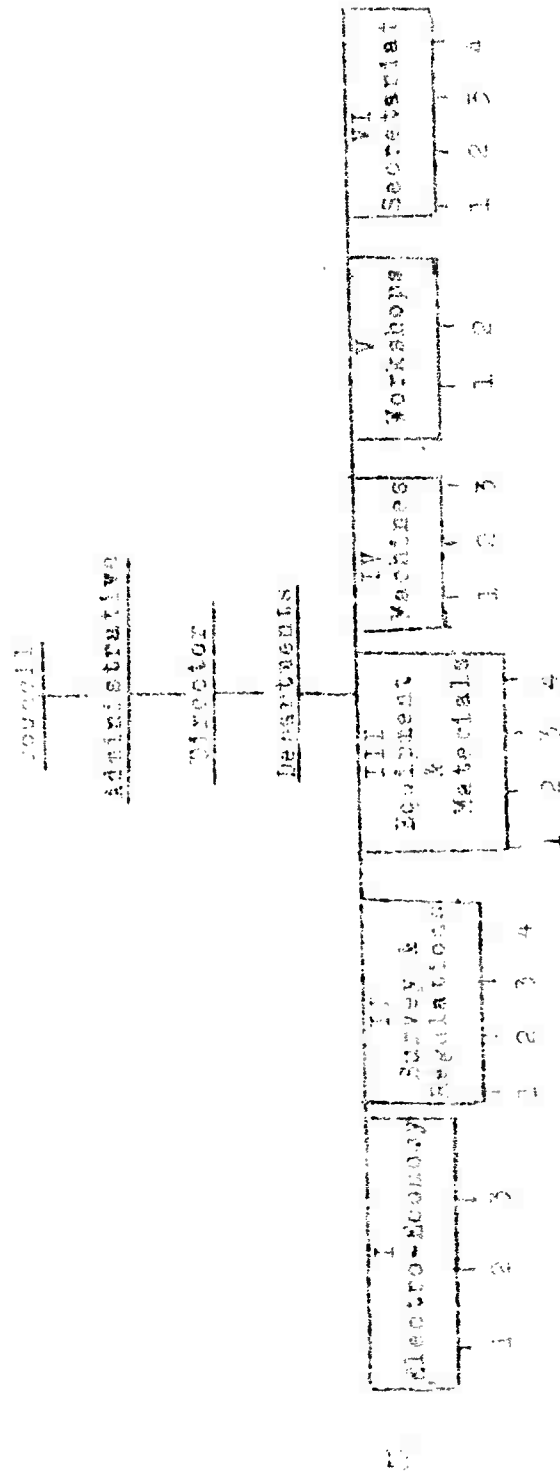


Figure 1. Organizational Chart of the Nikola Tesla Electro-Technical Institute in Belgrade

I Department of Electro-Economy:

- 1 - Systems analyzing group
- 2 - Study group
- 3 - Group for electrification of agriculture

II Department of Survey and Regulations:

- 1 - Measurement group
- 2 - Regulations group
- 3 - Electro-thermal group

III Department of Equipment & Materials:

- 1 - Equipment group
- 2 - High voltage group
- 3 - Group for materials
- 4 - High voltage laboratory group

IV Department of Machines:

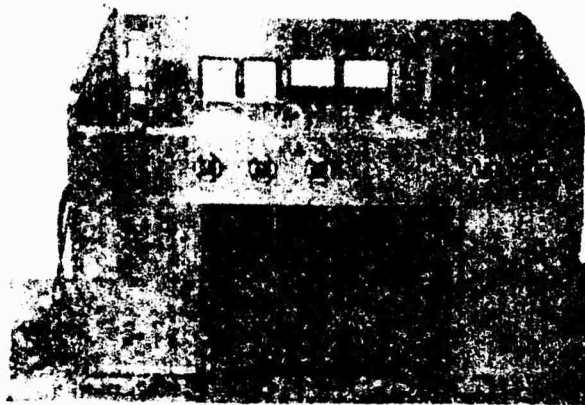
- 1 - Transformers group
- 2 - Rotational machinery group
- 3 - Machinery group

V Workshops

- 1 - Mechanical workshops
- 2 - Electro-technical workshop

VI Secretariat:

- 1 - Library and documentation
- 2 - Administrative department
- 3 - Commercial department
- 4 - Bookkeeping



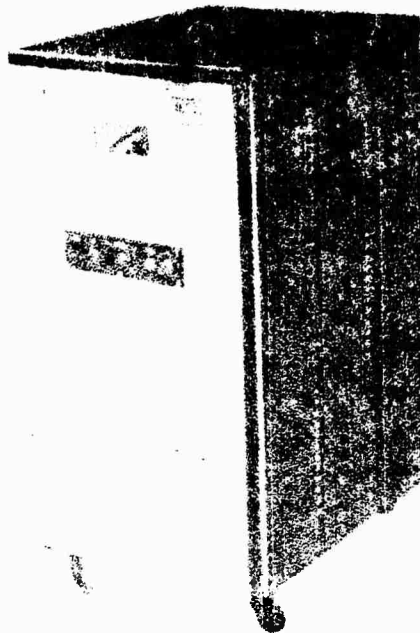
Sl. 2 -- Merni i komandni pult Epsteinovog aparata

Figure 2. Control Panel of Epstein Apparatus



Sl. 3 -- Postavljanje kidonografa na dalekovod 110 kV pod naponom.

Figure 3. The Installation of the Cidonograph on the 110 kV Power Line under Load



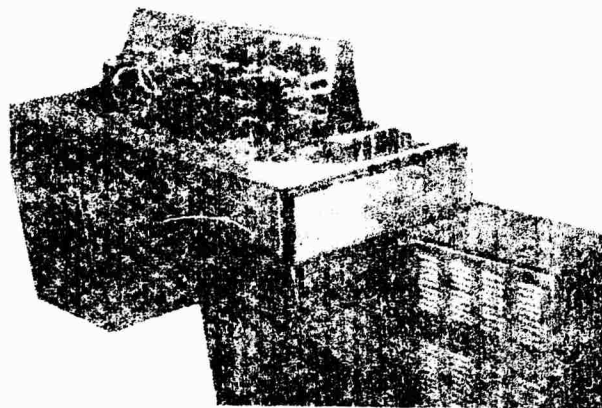
Sl. 4 -- Izgled uređaja za otsecanje udarnog talasa.

Figure 4. The View of the Equipment for Cutting the Striking Waves.



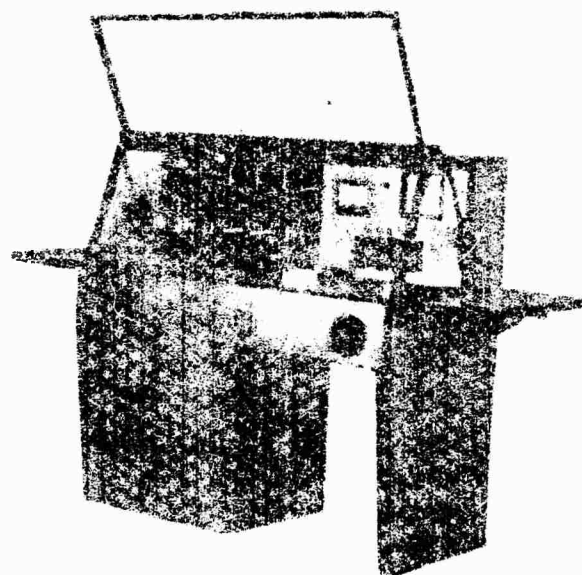
Sl. 5 -- Unutrašnjost uređaja za otsecanje udarnog talasa.

Figure 5. The Interior of the Equipment for Cutting the Striking Wave



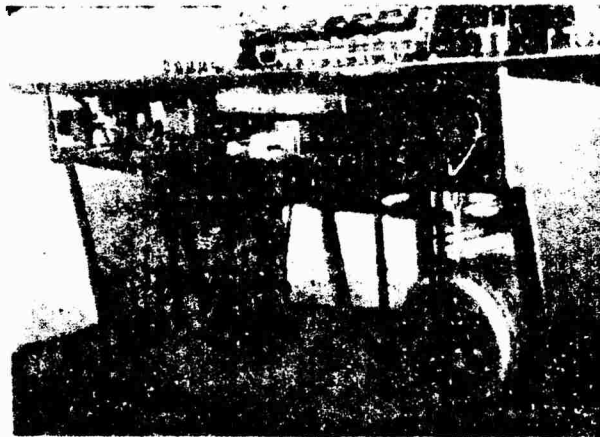
Sl. 6 — Izgled uređaja za strujno ispitivanje zaštitnih prekidača.

Figure 6. The View of the Equipment for Testing Currents of Protective Switches



Sl. 7 — Unutrašnjost uređaja za strujno ispitivanje zaštitnih prekidača.

Figure 7. The Inside View of the Equipment for Testing Currents of Protective Switches



Sl. 8 -- Uređaj za naponsko ispitivanje zaštitnih prekidača.

Figure 8. The Installation for The Testing of Voltage of Protective Switches.

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